National Transportation Safety Board
Aviation Incident Final Report

Location:	Cripple Creek, CO	**Incident Number:**	DEN07IA055
Date & Time:	01/25/2007, 1647 MST	**Registration:**	N17337
Aircraft:	Bombardier, Inc. CL-600-2B19	**Aircraft Damage:**	Minor
Defining Event:		**Injuries:**	54 None
Flight Conducted Under:	Part 121: Air Carrier - Scheduled		

Analysis

While climbing through FL 240, the No. 1 engine experienced a fan disk separation, which resulted in the separation of the inlet, fan rotor assembly, the fan containment case, and portions of the thrust reverser. The airplane reversed course and landed without further incident. Postincident examination revealed minor damage to the aft portion of the fuselage and empennage. An examination of the remaining airplane systems revealed no anomalies. Portions of the fan disk were recovered and examination of the fan disk revealed fatigue striations emanating from the aft bore corner of the fan disk. The striations came from an area that exhibited characteristics consistent with arc-out damage, which was the result of improper assembly and marking procedures during the electrochemical etching process. This damage was not detected during the manufacturer's quality assurance process used by the manufacturer. Further, the operator did not detect this damage while conducting the inspections prescribed through required airworthiness directives because the inspection procedures required were not detailed enough to detect the arc-out damage and the maintenance personnel did not receive appropriate training. Following the incident, the manufacturer issued alert service bulletins and the FAA issued an airworthiness directive to resolve these issues.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: A fatigue fracture, which resulted in the separation of the No.1 engine fan disk. Contributing factors in the accident were the operators' maintenance personnel lack of training to be able to detect arc-out damage on the fan disk, and the fan disk manufacturer's inadequate electro-chemical etch match marking process of the fan disk to forward fan shaft that allowed for the initiation of a fatigue point that was undetected at the time of original manufacture.

Findings

Occurrence #1: AIRFRAME/COMPONENT/SYSTEM FAILURE/MALFUNCTION
Phase of Operation: CLIMB - TO CRUISE

Findings
1. (C) COMPRESSOR ASSEMBLY,FORWARD FAN - FATIGUE
2. (C) COMPRESSOR ASSEMBLY,FORWARD FAN - SEPARATION
3. (F) MAINTENANCE,INSPECTION - INADEQUATE - OTHER MAINTENANCE PERSONNEL
4. (F) MISCELLANEOUS - NOT DETECTED - MANUFACTURER
5. (F) IMPROPER USE OF PROCEDURE - MANUFACTURER

Occurrence #2: LOSS OF ENGINE POWER(TOTAL) - MECH FAILURE/MALF
Phase of Operation: CLIMB - TO CRUISE

Factual Information

HISTORY OF FLIGHT

On January 25, 2007, at 1647 mountain standard time, a Bombardier CL-600-2B19, N17337, operated by Mesa Airlines, doing business as U.S Airways Express flight 2985, sustained minor damaged when it experienced a fan disk separation while climbing through approximately 24,000 feet (FL240), 8 miles west, southwest of Cripple Creek, Colorado. Day visual meteorological conditions prevailed at the time of the incident. The regularly scheduled domestic passenger flight was being operated under the provisions of Title 14 Code of Federal Regulations (CFR) Part 121 on an instrument flight rules flight plan. The captain, first officer, flight attendant, Federal Aviation Administration (FAA) inspector, and 50 passengers were not injured. The flight departed Denver International Airport (DEN), Denver, Colorado, at 1629 and was en route to Phoenix, Arizona.

According to an interview, subsequent telephone conversations, and a written statement from the flight crew, they were climbing through approximately FL240 when they heard a loud pop and experienced a vibration or buffet. The airspeed began to slow. The crew reported that they were not able to maintain a climb configuration or a level altitude, and initiated a controlled descent. They observed a "no oil pressure" indication for the number one engine along with a maximum indication on the N1. Thrust was reduced to idle power.

The crew reported that they reversed course for a return to DEN, and were able to maintain an altitude of 12,000 feet mean sea level (msl). The flight crew received vectors for a visual approach and landed uneventfully. The crew did not report any airplane controllability issues after the separation.

DAMAGE TO AIRCRAFT

The National Transportation Safety Board investigator-in-charge (IIC) arrived at DEN approximately 0800 on January 26, 2007. The Safety Board IIC, a Safety Board powerplant engineer, a Safety Board structural engineer, the FAA Aviation Accident Investigation (AAI-100) IIC, and representatives from Bombardier, General Electric (GE) Aviation, and Mesa Airlines, examined the airplane and number one engine on January 27 and 28, 2007. Examination of the number one engine revealed that the inlet, fan rotor assembly, fan containment case, and portions of the thrust reverser (TR) were all missing. Examination of the airplane revealed damage to the fuselage, in-line with the plane of rotation of the number one engine fan rotor, and marks on the vertical and horizontal stabilizers.

PERSONNEL INFORMATION

The pilot, age 40, held an airline transport pilot certificate with an airplane multi engine land rating, and a commercial pilot certificate with an airplane single engine land rating. In addition, he held type ratings in the Beech BE-1900 and CL-65. He was issued a first class airman medical certificate on November 2, 2006. The certificate contained no limitations. According to Mesa Airlines, the pilot had logged approximately 11,000 hours total time; 4,000 of which were in the make and model of the incident airplane.

The first officer, age 34, held a commercial pilot certificate with airplane single engine land, multi engine land, and instrument ratings. In addition, he held a type rating in the CL-65, with the limitation of second-in-command privileges only. He was issued a first class airman

medical certificate on February 16, 2006. The certificate contained the limitation "must wear corrective lenses." According to Mesa Airlines, the first officer had logged approximately 3,700 hours total time; 2,300 of which were in the make and model of the incident airplane.

AIRCRAFT INFORMATION

The incident airplane, a Bombardier CL-600-2B19 (serial number 7337), was manufactured in 1999. It was registered with the FAA on a standard airworthiness certificate for transport operations. The airplane was powered by two GE CF34-3B1 (serial number 872749 and 872190, number one and two respectively) turbo fan engines.

The airplane was registered to Wells Fargo Bank, operated by Mesa Airlines, and was maintained under a continuous airworthiness inspection program. At the time of the incident, the airframe had 19,629 hours total time, and 15,438 total cycles. The incident engine (No. 1) had 13,627 hours time since new (TSN), and 10,849 total cycles since new (CSN). According to the Engine Service Record, the incident engine was installed on the event airplane on January 10, 2007. Previously, the No. 1 engine had been installed on a company airplane; serial number (SN) 7410.

METEOROLOGICAL CONDITIONS

The closest official weather observation station was Colorado Springs Municipal Airport (COS), Colorado Springs, Colorado, located 32 nautical miles (nm) east, northeast of the incident site. The elevation of the weather observation station was 6,187 feet msl. The routine aviation weather report (METAR) for COS, issued at 1654, reported, winds, 140 degrees at 9 knots, visibility, 10 statute miles; sky condition, clear, temperature 05 degrees Celsius (C); dewpoint, minus 04 degrees C; altimeter, 30.18 inches.

FLIGHT RECORDERS

Cockpit Voice Recorder

The airplane was equipped with a Fairchild Model A 100S 30-minute solid-state cockpit voice recorder (CVR). The CVR was secured and sent to the National Transportation Safety Board's (Safety Board) Audio Laboratory for readout. The CVR had not sustained any heat or structural damage and the audio information was extracted normally from the recorder. The recording consisted of four channels of excellent quality audio information. The arrival and landing back into DEN was captured on the recording. The engine separation occurred prior to the start of the recording. A CVR group was not formed and a transcript was not prepared.

Flight Data Recorder

The airplane was equipped with an L-3 Communications Fairchild Model F1000 digital flight data recorder (DFDR), which recorded 412 parameters of airplane flight information using solid state media as a recording medium. The DFDR was secured and sent to the Safety Board Vehicle Recorders Laboratory for readout. The DFDR had not sustained any heat or structural damage and the information was extracted normally from the recorder. A DFDR group was not formed. For this incident, 82 parameters were checked and validated, and a report was prepared.

Review of the DFDR data showed that the takeoff and climb were normal. At a time(T) of T = 546 seconds (9 minutes and 6 seconds after takeoff and 4 minutes and 9 seconds prior to the

fan disk separation) the vibration level for the No. 1 engine fan rotor assembly (N1) started to increase from a relatively stable level around 0.7 mils. At T = 635 seconds, the vibration level reached over 1 mil and continued to steadily increase to 1.5 mils and 1.8 mils at T = 746 seconds and T = 789 seconds, respectively. After T = 789 seconds, the vibration quickly increased and reached its maximum value of 2.65 mils at T = 794 seconds, corresponding to the time just before the fan disk separation.

The fan rotor assembly, just prior to the fan disk separation, had been stable at approximately 95 percent N1 and the airplane was steadily climbing at around 290 knots. At the moment identified as the fan disk separation, the fan rotor speed had increased to 99.6 percent N1 and the airspeed started to decrease; however the airplane continued to climb for another twelve seconds before the pilot initiated a descent. The fan rotor assembly speed reached its peak, 133.94 percent N1 one second after the disk separation, and immediately started to decrease. The fan rotor assembly speed continued to decrease and eventually reach zero percent N1 at T = 879 seconds (1 minute 24 seconds after the fan disk separation). The airplane's airspeed and altitude eventually stabilized at 200 knots and 11,000 feet, respectively as the airplane returned to DEN.

MEDICAL AND PATHOLOGICAL INFORMATION

FAA toxicological tests were not performed on the flight crew. Both crew members submitted specimens for drug screening following the incident. Tests for marijuana, cocaine, amphetamines, opiates, and PCP were all negative.

TESTS AND RESEARCH

Airframe Examination

A detailed examination of the damage to the airplane fuselage was conducted on January 27, 2007. The airplane sustained damage to the fuselage in-line with the plane of rotation of the event engine fan rotor, as well as marks on the vertical tail, the right horizontal stabilizer, and left engine pylon damage. The damage to the airplane fuselage was comprised of denting, one puncture measuring approximately 5 inches by 2 inches, a skin tear measuring approximately 8 inches in length, and several scrape and gouge marks. The left engine pylon was deformed and fractured forward of the forward engine mount, and the forward engine mount exhibited minor scoring damage.

Engine Examination

A detailed on wing examination of the No. 1 engine was conducted on January 27 and 28, 2007, in a United Airlines hangar located at Denver International Airport. Representatives from the Safety Board, FAA, Bombardier Aerospace, and General Electric were present during this examination.

An examination of the incident engine revealed that the inlet, the fan disk, the forward fan case assembly, and the TR assembly were all missing except for a small piece of the aft flange of the fan disk that remained attached to the fan forward shaft, the rear flange of the forward fan case which remained attached to the fan aft case, and four TR blocker doors. Pieces of the Kevlar® wrap, used as the ballistic shrapnel-resistant shielding within the forward case assembly, were found entangled with the remains of the fan case assembly aft flange.

Fan Disk Search and Recovery

On January 31, 2007, a search team comprised of persons from the Safety Board, FAA, and GE, supported by the Teller County Sheriff's Department and an aircraft recovery company, conducted a ground search for engine parts, with an emphasis on recovering the fan disk. A section of the fan disk, several loose fan blades, parts of the engine cowling and TR, the engine spinner, and pieces of the fan containment case were recovered.

The recovered fan disk section represented approximately one third of the entire disk, from pinhole 20 through 28, with the interior ends of pinholes 1 and 19. Five full-length fan blades, one half-span blade, and three blades fractured above the platform remained attached to the disk piece. The search did not recover any additional pieces of the fan disk. The fan disk section was shipped as recovered to the materials laboratory in Washington, D.C. for metallurgical examination.

Metallurgical Examination

The Safety Board materials laboratory metallurgists along with representatives from General Electric examined the fan disk from February 5-7, 2007. A summary of the findings follows.

According to the metallurgical report, examination of the fan disk revealed it had fractured through the blade retention pinholes of 1 and 19. Visual examination of the fracture area intersecting pinhole 19 revealed large areas of gross plastic deformation, bulk material yielding, and highly textured shear lips, all indicative of tearing overstress separations. The fracture intersecting through pinhole 1 exhibited a finely textured flat region located at the aft bore corner of the aft disk and a faint curved crack arrest mark that delineated a transition from the smooth textured region to the rough surrounding region.

A section of the aft fan disk bore containing the smooth textured region was saw cut and examined using a scanning electron microscope (SEM). Fatigue striations were observed coming from the aft bore corner in an area containing a depression and raised material. The fatigue region measured 0.016 inches along the bore and 0.0185 inches at the aft face. The raised material region had a blue-to-straw color, typical of high temperature exposure of the titanium to air, and consistent with localized electrical arc damage (also referred to as 'arc-out' damage) that melts the surrounding area then resolidifies into a smooth raised fusion zone or nugget. Two overlapping fusion zones were noted in the raised material area. The entire arc area measured approximately 0.055 inches radially along the edge of the hub corner, of which, the raised fusion zone accounted for about 0.035 inches. Based on projections from the existing undamaged disk surfaces, the original longitudinal size of the fusion zone was estimated to be between 0.025 inches and 0.030 inches; therefore the entire arc damage area was estimated to be 0.055 inches by 0.050 to 0.060 inches.

The fracture region adjacent to the fusion zone displayed several ratchet mark like features. Propagating from each of the ratchet marks, were closely spaced fatigue striations. The closely spaced fatigue striations propagating from each of the ratchet marks was indicative of multiple fatigue origins at the fusion zone interface. GE produced a curve of striation density versus measured crack length to determine the estimated number of cycles for the crack to propagate to failure. The curve showed a rapid drop in measured striation densities from the fracture origin that, according to GE, is a characteristic consistent with mission (flight) driven low cycle fatigue (LCF) crack propagation mechanisms. An estimated 15,000 cycles was calculated across the fracture to the estimated fatigue crack end starting at the edge of the remaining arc nugget fracture. According to the maintenance records, fan disk SN GEE1486K had

accumulated 10,849 CSN at the time the fan disk separation. GE performed an analytically prediction of the striation densities for an initial flaw size of 0.023 x 0.018 inches and created a curve that was overlaid on the measured striation density curve from the failed fan disk. Based on the two curves, GE concluded there that was excellent correlation between the measured and the predicted striation densities and the fatigue crack initiated and propagated very early in the life of the component.

An energy dispersive X-ray spectroscopy (EDS) spectra from the fracture surface was consistent with the specified material, Titanium (Ti) -17. Core microstructure, well away from the arc region, was composed of acicular alpha in a matrix of transformed beta, a structure consistent with the specified processing of the fan disk material.

The Safety Board performed a series of tests to produce exemplar electrical arc damage to compare it with the damage observed on the failed fan disk. Electrical arcs were produced on sections of the failed fan disk using direct current at an arbitrarily chosen 28 volts, with the maximum current flow of 50 amps. A positively charged brass (copper zinc alloy) rod was brought close to the negatively charged fan disk section and two arc indications were produced. The current polarity was then reversed (probe negative) and four more arc indications were produced. During the experiment the brass rod contacted the fan disk section in several occasions.

The positive probe arc indications tended to be somewhat larger in the affected area than the negatively charged probe arcs, 0.07 to 0.08 inch versus 0.04 to 0.05 inch. Furthermore, the central fusion zone region for a positively charged probe arc was depressed with an eroded or washed out appearance whereas for a negatively charged probe the fusion zone had a built up central peak.

ADDITIONAL INFORMATION

Arc-Out Events

Prior to the fan disk separation, there had been 30 previous CF34 fan disks with arc-out damage, some of which with multiple damage sites, but none of which resulted in a fan disk separation. GE first discovered that CF34 fan disks had been arc damaged in June 2000, when an operator reported a crack in the forward tang of a CF34 fan disk. GE initiated a root cause investigation and found that the crack had initiated from a site where electrical arc-out damage was present. The source of the electrical arc-out damage was believed to have been the electro-chemical etch permanent marking procedure used to match mark the fan disk and forward fan shaft during initial engine assembly at GE. GE concluded that the arc-out damage was caused during the electro-chemical etching process by a grounding wire attached to a stud located on the forward spinner cone flange becoming inadvertently loose and contacting the disk while the power was on to the etching machine.

On August 4, 2000, General Electric issued an alert service bulletin (ASB) CF34-AL SB 72-A0103 for certain CF34 engines and certain CF-34 engines with particular fan disk serial numbers. According to the ASBs, CF34 fan disks were to be visually inspected using a flashlight, inspection mirror, a 3x magnifying glass, and an arc-out reference standard by an inspector who has been trained in arc-out inspection techniques. If the inspector had not had the appropriate arc-out inspection training, the inspection was to be performed under the guidance of a GE representative who had been trained in arc-out detection. Once properly trained, the ASBs allowed an inspector from the airlines to train fellow inspectors at the

company in lieu of each individual inspector receiving training from GE. Also, both ASBs did not specify calendar time in which all the engines were to be inspected, the length of time the arc-out inspection training was acceptable, how often that inspection must be performed in order for the inspector to be considered proficient, and how often recurrent training, if any, must be taken to ensure a certain skill level. However, in revision 3, dated May 13, 2005, ASB 72-A0103 did recommend that the arc-out inspection be performed within no more than 2 years. Since their initial release, both ASBs have been revised to update the list of affected fan disks and to clarify the recommended compliance times; however, the inspection requirements were not changed or modified.

The FAA followed ASB CF34-AL SB 72-A0103 with the issuance of an Airworthiness Directive (AD) 2001-10-03 on May 7, 2001, with an effective date of May 31, 2001. The AD required compliance with paragraphs 3.A. (1) through 3.A. (2)(f) of the accomplishment instructions of ASB 72-A0103. This inspection was to be complied with before 8,000 cycles since new, the next hot section inspection, or within 120 days of the effective date of the AD. The FAA issued AD 2006-05-04 on March 3, 2006, to supersede the previous AD, to correct an error in the original AD.

After the fan disk separation, GE reviewed all the confirmed CF34 fan arc-out data and discovered that, although the vast majority of the arc-out locations were on the front face of the front disk (22 out of 31; 70 percent), there were five, including the event fan disk separation, that were located in the fan disk bore area and in all five cases the same operator/assembler had performed the fan disk and forward fan shaft match marking procedure.

Review of all the CF34 fan disk subassembly build records revealed that the operator/assembler who had matched marked the fan disk and forward fan shaft on the event engine, SN 872749, had also match marked 39 other fan rotor assemblies, including the next CF34 engine in the build sequence (referred to as the 'sister' engine), SN 872750, which also belonged to Mesa Airlines. Due to the high potential for arc-out damage on the 'sister' engine, GE requested that fan disk installed in engine SN 872750, SN GEE1480F, be removed and sent to GE for metallurgical examination. An arc-out indication measuring approximately 0.23 by .055 inches was observed on the forward spinner cone flange aft corner. The disk had accumulated approximately 11,000 cycles and 13,000 hours when removed from service.

CF34 Part Marking Process

The instructions for building the fan disk subassembly are provided in the workstation (WS) 1280 fan disk sub assembly instructions, which include instructions for part identification marking and match marking. Match marking is imprinted into two or more adjoining parts for purposes of realignment when the parts are reassembled. In the case of the fan disk rotor assembly, the permanent match mark indicates the proper dynamic alignment of both the bladed fan disk and forward fan shaft, which is also referred to as the "0" (zero) balance mark. At the time the fan disk sub assembly for engine SN 872749 had been assembled between February and March 2000, six authorized permanent part marking methods were listed in CF34 EM task 72-09-01 Special Procedure 41 titled MARKING OF PARTS. The six (6) permanent part marking procedures were as follows: 1) metal stamp, 2) vibropeen, 3) scribe, 4) acid-etch, 5) electro-chemical etch, and 6) blast.

According to the engine SN 872749 fan disk sub assembly instructions, after the fan disk rotor assembly is dynamically balanced, the fan disk and the forward fan shaft are match marked in

accordance with Operation No. 55 (sequence No. 45) per method 7A2. The GE permanent marking method specification P23TF3-S38, method 7A2 is an electro-chemical etch marking process, intermediate depth. Electro-chemical etch is a method for permanently marking parts by slowly and uniformly eroding away material by causing an electrically induced chemical reaction at the surface of the part. An electrical current is passed through an electrolyte saturated wick pad and through a stencil resting on the surface of the part. The charged electrolyte reacts with the surface of the part through the openings in the stencil creating an impression.

In the Operation No. 55 detailed marking instruction sheets, the first step was to permanently mark the fan disk, while it was still mated with the forward fan shaft, with an "0" in line with the No. 1 hole position using an electro-chemical etch method in accordance with Operating Procedure/Instruction (O.P.I.) 2568. After the fan disk was marked, the instructions called for the forward fan shaft bore to be temporarily marked while the fan disk and forward fan shaft remained bolted together (Step 2). Once the forward fan shaft bore is temporarily marked, the attachments nuts are removed and the forward fan shaft is separated from the fan disk (Step 3) before the permanent electro-chemical etch match marking of the forward fan shaft occurs. Match marking of the forward fan shaft is performed by marking the bore of the shaft with a "0" (Step 3A) in-line with the "0" on the fan disk.

GE has since changed the match marking method used on the fan disk and the forward fan shaft for the CF34 engine. Following the June 2000 discovery of a cracked CF34 fan disk caused by arc-out damage, GE immediately discontinued the use of electro-chemical etch as a part number method on CF34 fan disks and revised the detailed marking instruction sheets (Operation No. 55) to change the permanent marking process from electro-chemical etch method 7A2 to grit blast method 8A and rearranged the operational steps to facilitate the new marking requirement (change incorporated June 14, 2000). In October 2000, GE also discontinued the use of electro-chemical etch on CF34 engines for match marking the fan disk and forward fan shaft and revised Operation No. 55 sheets to specify grit blast method 8A as permanent marking method (change incorporated October 12, 2000).

Fan disk arc-out damage had been previously thought to have occurred during the electro-chemical etch process when the grounding wire would become inadvertently loose and contact the disk front face; however, since the arc-out damage on the incident disk was found in the aft bore, an alternate scenario was considered more plausible. Instead, GE considered the more likely scenario to be that the operator/assembler inserted the brass marking rod through the fan disk bore in order to match mark the forward fan shaft with the fan disk still attached and while doing so inadvertently contacted the fan disk bore while the power was on creating the arc-out damage.

A review of the Operation No. 55 detail match marking procedures, revealed that at no time during the electro-chemical etch process was the brass marking rod used to imprint the forward fan shaft required or authorized to be placed inside the bore of the fan disk. Furthermore, the instructions were clear that the forward fan shaft would be only temporally marked while the fan disk was still attached and that the permanent marking of the forward fan shaft would occur only after it had been separated from the fan disk.

GE Match Marking Process Controls and Inspection

A review of the Operation No. 55 detailed match marking procedure in affect at the time the

event fan sub assembly was built revealed that there were no inspection requirements for damage to the fan disk or forward fan shaft after the electro-etch procedure or after the No. 1 bearing was completely assembled. Instead, visual inspections for proper part marking or any physical damage were called out in the WS 1280 fan disk sub assembly instructions sheets Operation No. 65. Operation No. 65 provided a series of visual inspections for proper assembly identification markings, match marking, fan blade retaining pin markings, and damage to any component, with sequence Nos. 190/195 stating to "Visually Inspect All Components for Physical Damage". According to GE, this physical inspection for damage is performed in accordance with the Inspector Certification Program that defines physical damage; however, arc-out damage was not specifically referenced. The current Operation No. 55 detailed marking instructions also does not have specific visual inspections requirements for damage but instead relies on the inspection requirements WS 1280 fan sub assembly instructions.

Mesa Airlines Maintenance Records

Mesa Airlines provided the Safety Board IIC with a copy of the maintenance records for the incident airplane and the event engine. A review of the maintenance records indicated that the incident engine had not been overhauled and the last major engine maintenance action was conducted by Lufthansa Aero LLC., Service Center, Tulsa, Oklahoma, in November 2005, to replace hot section parts.

The incident engine had accumulated 10,498 hours TSN and 8,490 CSN at the last major maintenance action. A review of the 60-day history for the airplane, prior to the fan disk separation, revealed no squawks or maintenance write-ups for the incident engine. A review of the engine logbook service bulletin compliance section and the engine service record section showed no annotation that ASB CF34-AL SB 72 -A0103, AD 2001-10-03, or AD 2006-05-04 had been complied with or accomplished. A review of Engineering Order (EO) for AD 2001-10-03, and the Airworthiness Directive Index for the incident engine revealed that the inspection for the event disk was conducted on August 3, 2005, at a total cycle time of 7,911. No discrepancies were noted at the time of the inspection.

According to the ASB and EO, "if the inspector performing the following inspection procedure has not been trained in arc-out inspection techniques, the inspection should be done under the guidance of a GE representative who has been trained. The operator's inspector who performed the first inspection can then perform subsequent training of other inspectors at the operator's facility." According to GE's aviation field service engineer for Mesa Airlines, the mechanic who prepared the fan disk for inspection was trained at the Mesa Airlines facility in Fresno, California. An exact date for training could not be established, as GE did not maintain attendance rosters or training records, and the training was not recorded in the mechanic's training records maintained by Mesa Airlines.

The GE field service engineer stated that he did not provide training for the inspector who inspected the fan disk. No record of the arc-out training was recorded in the inspector's training record. In a statement provided by the inspector, he stated that he performed the inspection on the incident fan disk, not the mechanic who signed off as performing the inspection. He stated that the mechanic "initially prepared the fan disk and [he] performed the inspection." He stated further that the GE field service engineer trained him in July of 2005, in Phoenix, Arizona.

Corrective Actions

On January 26, 2007, the day after the separation, GE issued an All Operator's Wire (AOW) CF34-07-01 informing CF34 operators of the fan disk separation and that GE would be assisting the Safety Board in the investigation. On February 13, 2007, AOW CF34-07-02 was issued to update CF34 operators on the status of the investigation. The AOW stated that the fan disk separation had originated from an arc-out indication and that the airline operator had reported that they had previously complied with ASB 72-A0103.

On February 15, 2007, GE issued ASBs CF34-AL SB 72-A0232 and CF34-BJ SB 72-A0213 informing operators that, based on reviewing all available assembly and inspection records for CF34 fan disk, it was determined that fan disks marked by one specific operator/assembler had a higher susceptibility of arc-out damage in the fan disk bore, like that found on the incident fan disk. This represented a subpopulation of high priority fan disks that were considered to be at a higher risk of arc-out damaged and had not yet had a maintenance shop inspection. Each ASB provided: 1) a list of suspect fan disk serial numbers that had been assembled by the same operator/assembler that had not yet had an enhanced shop level inspection, 2) instructions on how to perform the one-time on-wing visual and tactile inspection, and 3) recommendations that the inspection be performed immediately. Although it was recommended that the person performing the inspection be trained in arc-out inspection techniques, it was not required. Both ASBs also request that the results of the inspection be reported back to GE. The total population number of high risk disks was 31, with 28 and 3 from the airline and the business jet fleets respectively.

On February 16, 2007, the FAA issued AD 2007-04-51 mandating the inspections called out in ASBs 72-A0232 and 72-A0213 be performed within the next 20 engine flight hours. Unlike the recommendations in the ASBs, AD 2007-04-51 did not require reporting of inspection results to either to GE or to the FAA.

That same day, GE issued AOW CF34-07-03 informing CF34 operators of GE's proposed three (3) phase field management plan to inspect all CF34 fan disks for arc-out damage. Phase 1 proposed immediate inspection of those fan disks with the highest susceptibility to arc-out damage that had not had an enhanced shop level inspection. AD 2007-04-51 addressed GE's proposed Phase 1 plan. Phase 2 proposed issuing SBs to introduce a new one-time on-wing tactile and enhanced visual (TEV) inspection for those fan disks previously inspected in accordance with AD 2001-10-03 or AD 2006-05-04 that had not had an enhanced shop level inspection, approximately 300 fan disks in total, within 500 engine flight hours after the ASBs are released. The ASBs would recommend that all operators be specifically training by GE in arc-out inspection technique and in order to comply with the ASBs, two trained inspectors would have to perform and sign-off on the inspection. Phase 3 proposed a new shop level inspection that would include a visual, fluorescent penetrant inspection (FPI), and eddy current inspection (ECI) no later than 5,000 hours.

On February 28, 2007, the FAA issued AD 2007-05-16 with an effective date of March 12, 2007, to supersede AD 2007-04-51 and to add eight additional engine serial numbers to the list of suspect fan disks. To date, 37 of the 39 fan disks listed in AD 2007-05-16 have been inspected with three confirmed to have arc out damage. The remaining two fan disks are installed in engines that are either in long term storage or installed in aircraft currently not in service.

On March 7, 2007, GE released three ASBs to address the proposed Phases 2 and 3 of their field management plan. ASB CF34-AL SB 72-A0231 focused on Phase 2 of GE's management

plan by recommending that all airline fleet fan disk that had not previously had a detailed shop inspection be inspected on-wing within 500 engine flight hours from the issuance of the ASB. Compliance with the ASB would require that two inspectors perform the inspection independently using a CF34 fan disk TEV inspection kit specially developed for this on-wing inspection and which could only be obtained after successful completion of the GE provided class. The TEV inspection tool kit includes tactile tools, flashlights, and specially designed mirrored fixtures to facilitate examination of the fan disk bore, and a serialized reference standard. No such tooling kits, specialized training, or a second inspector were either provided or required for the original arc-out inspection ASBs issued back in 2000.

ASBs CF34-AL SB 72-A0233 and CF34-BJ SB 72-A0212, focused on Phase 3 of GE's management plan by recommending, in addition to the fan rotor assembly inspection requirements in the EM (72-21-00), a TEV inspection of the fan disks. The EM inspection requirements current at the time of the fan disk separation included a Fluorescent Penetrant Inspection (FPI) and Eddy Current Inspection (ECI) for detection of cracks and a visual inspection for detection of arc-out indications; however, no tactical inspection was required and the visual inspection required no specific tooling nor provided detailed instruction on how or where to focus the inspection for arc-out damage. Compliance with ASB 72-A0233 would be within 5,000 hours from the issuance of the ASB and for ASB 72-A0212 compliance would be prior to accumulating 6,000 hours TSN or if a fan disk had greater than 5,500 hours within 500 flight hours. According to GE, the differences in the compliance times between ASB 72-A0233 and -A0212 were to accommodate established fleet maintenance intervals.

The FAA issued AD 2007-07-07, on March 30, 2007, with an effective date of April 23, 2007 to supersede AD 2006-05-04, and to mandate the inspections recommended in CF34-AL SB 72-A0231, CF34-AL SB 72-A0233, and CF34-BJ SB 72-A0212. The difference between the ASBs and the AD is that the AD added a time limit of five calendar years to the on-wing and shop-level inspection compliance time.

Other

Parties to the investigation included the FAA, as represented by an investigator from AAI-100 in Washington, D.C., Mesa Airlines, GE Aviation, and the Airline Pilot's Association. The Transportation Safety Board of Canada was an accredited representative with Bombardier, and Transport Canada as their technical liaison. The airplane and incident engine were released back to a representative of Mesa Airlines on January 28, and February 12, 2007, respectively.

Pilot Information

Certificate:	Airline Transport; Flight Instructor; Commercial	**Age:**	40, Male
Airplane Rating(s):	Multi-engine Land; Single-engine Land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	Seatbelt, Shoulder harness
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	No
Medical Certification:	Class 1 Without Waivers/Limitations	**Last Medical Exam:**	11/01/2006
Occupational Pilot:		**Last Flight Review or Equivalent:**	10/01/2006
Flight Time:	11000 hours (Total, all aircraft), 4000 hours (Total, this make and model), 250 hours (Last 90 days, all aircraft)		

Co-Pilot Information

Certificate:	Commercial	**Age:**	34, Male
Airplane Rating(s):	Multi-engine Land; Single-engine Land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	Seatbelt, Shoulder harness
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	No
Medical Certification:	Class 1 With Waivers/Limitations	**Last Medical Exam:**	02/01/2006
Occupational Pilot:		**Last Flight Review or Equivalent:**	04/01/2006
Flight Time:	3700 hours (Total, all aircraft), 2300 hours (Total, this make and model), 270 hours (Last 90 days, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Manufacturer:	Bombardier, Inc.	**Registration:**	N17337
Model/Series:	CL-600-2B19	**Aircraft Category:**	Airplane
Year of Manufacture:		**Amateur Built:**	No
Airworthiness Certificate:	Transport	**Serial Number:**	7337
Landing Gear Type:	Retractable - Tricycle	**Seats:**	55
Date/Type of Last Inspection:	01/01/2007, Continuous Airworthiness	**Certified Max Gross Wt.:**	53250 lbs
Time Since Last Inspection:	13 Hours	**Engines:**	2 Turbo Fan
Airframe Total Time:	19629 Hours	**Engine Manufacturer:**	General Electric
ELT:	Installed, not activated	**Engine Model/Series:**	CF34-3B1
Registered Owner:	Wells Fargo Bank Northwest NA Trustee	**Rated Power:**	9200 lbs
Operator:	MESA AIRLINES INC	**Air Carrier Operating Certificate:**	Flag carrier (121)
Operator Does Business As:		**Operator Designator Code:**	MASA

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual Conditions	**Condition of Light:**	Day
Observation Facility, Elevation:	KCOS, 6187 ft msl	**Observation Time:**	1654 MST
Distance from Accident Site:		**Direction from Accident Site:**	
Lowest Cloud Condition:	Clear	**Temperature/Dew Point:**	5°C / -4°C
Lowest Ceiling:	None	**Visibility**	10 Miles
Wind Speed/Gusts, Direction:	9 knots, 140°	**Visibility (RVR):**	
Altimeter Setting:	30.18 inches Hg	**Visibility (RVV):**	
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Denver, CO (KDEN)	**Type of Flight Plan Filed:**	IFR
Destination:	Phoenix, AZ (KPHX)	**Type of Clearance:**	IFR
Departure Time:	1629 MST	**Type of Airspace:**	

Wreckage and Impact Information

Crew Injuries:	4 None	**Aircraft Damage:**	Minor
Passenger Injuries:	50 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	54 None	**Latitude, Longitude:**	38.739722, -105.304167

Administrative Information

Investigator In Charge (IIC):	Jennifer S Kaiser	**Adopted Date:**	01/31/2008
Additional Participating Persons:	Eric Gust; Mesa Airlines; Phoenix, AZ Andre Tousignant; Bombardier; Montreal, Canada, David Gridley; GE - Aircraft Engines; Lynn, MA Katie Storo; ALPA; Herndon, VA TR Proven; FAA- AAI- 100; Washington, DC Elaine M Summers; Transportation Safety Board Canada		
Publish Date:			
Investigation Docket:	NTSB accident and incident dockets serve as permanent archival information for the NTSB's investigations. Dockets released prior to June 1, 2009 are publicly available from the NTSB's Record Management Division at pubinq@ntsb.gov, or at 800-877-6799. Dockets released after this date are available at http://dms.ntsb.gov/pubdms/.		